Designing Digital Problem Based Learning Tasks that Motivate Students

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This study examines whether teachers are able to apply the principles of autonomy support and structure support in designing digital problem based learning (PBL) tasks following specific training. We examine whether the designed PBL tasks after the training are more autonomy- and structure-supportive compared to the digital PBL tasks that teachers made before they had followed the training. And then it is examined whether primary and secondary school students experience greater autonomy, competence, and motivation in these tasks. Participants were 184 fifth-, sixth-, seventh- and eighth- grade students and 20 teachers. The results showed that teachers indicated that their digital PBL tasks were more autonomy- and structure-supportive after completing the training. Furthermore, students' perceived autonomy, perceived competence, and intrinsic motivation in the digital PBL tasks were higher after teachers completed the training. In addition, there was an interaction effect between training and school type on perceived autonomy, perceived competence, and intrinsic motivation. Compared to primary school students, secondary school students evidenced a greater increase in perceived autonomy, perceived competence, and intrinsic motivation on the PBL tasks.

INTRODUCTION

Computer-supported learning environments based on a constructivist instructional approach provide students with access to a variety of open-ended applications that help them construct more complex understandings (Savery & Duffy, 1995). An example of such an environment is a digital problem based learning (PBL) task (Liu & Bera, 2005). In these tasks, students have opportunities to apply their content knowledge and skills while working on contextualized problems (Dunlap, 2005). The learner acts as an active seeker of information who revises and updates his or her knowledge through the process of gathering new information rather than providing the single correct answer to a question (Niederhauser & Stoddart, 2001). Because hypermedia provide rich information resources through various forms of media (e.g., texts, images, and video sequences), multiple related problems can be presented in one environment (Hoffman & Ritchie, 1997). Digital PBL tasks offer students autonomy and have a positive effect on students' motivation and learning outcomes (Mayer, 2011).

However, it seems that many teachers do not have the expertise to construct effective PBL tasks. Digital PBL tasks in the classroom often provide such a large amount of information and autonomy that students experience information overload, do not make effective choices and become lost due to the information that they receive (Azevedo & Witherspoon, 2009). PBL tasks are often ill-structured, which places increased demands on learners, as indicated by superficial information processing (Liu & Bera, 2005), relatively high dropout rates and a diminished ability to focus during learning (Mayer, 2011).

To avoid excessive associative distraction, digital PBL tasks must contain not only autonomy support but also structure support (Van Loon, Ros, & Martens, 2012). Previous research of Van Loon et al. (2012) shows that a digital PBL task that combined autonomy support and structure support had a positive effect on students' intrinsic motivation and learning outcomes.

Autonomy support ensures that students feel control over their actions (Reeve, Nix, & Hamm, 2003) and structure support makes the learning environment less chaotic and more consistent and predictable for students (Guay, Ratelle, & Chanal, 2008). These two principles are derived from the Self-Determination Theory (SDT), which is an influential theory regarding motivation (Deci & Ryan, 2000). By specifying the contextual environments that foster optimal learning, SDT is a relevant framework for the study of favourable conditions for digital learning. According to SDT, intrinsic motivation and deep learning occur when a learning environment facilitates a student's perceived autonomy, perceived competence, and perceived relatedness (Deci & Ryan, 2000). A digital PBL task can facilitate perceived autonomy and perceived competence through autonomy support by encouraging students to make choices and follow their own learning path and through the necessary structure support by providing the guidance that they need. Research studies on learning in the classroom show that offering autonomy support and structure support together positively affects student motivation (Jang, Reeve, & Deci, 2010), including in digital learning with PBL tasks (Van Loon et al., 2012).

To realize motivated students and a good learning result, both autonomy and structure support are important in digital PBL tasks (Van Loon et al., 2012). However, the question is whether teachers can bring these principles into practice when they are designing digital PBL tasks. This is not simple because teachers often believe that autonomy support and structure support are two opposite principles. According to Reeve, Deci, and Ryan (2004a), autonomy support and structure support are separate dimensions of a learning environment that motivates students. In fact, the opposite of an autonomy-supportive environment is a *controlling* environment (Reeve, Jang, Carrell, Jeon, & Barch, 2004b). A controlling environment is characterized by extrinsic incentives and pressuring language, which tend to interfere with student motivation (Reeve et al., 2004b).

The current study builds on Van Loon et al.'s (2012) finding that when autonomy support and structure support are present, digital PBL tasks in a hypermedia environment have a positive effect on students' intrinsic motivation and learning outcomes. The present study examines whether teachers can be trained to apply the principles of autonomy support and structure support in their digital PBL tasks and whether students in primary and secondary education experience greater autonomy, competence, and motivation while working on these tasks compared to the digital PBL tasks that teachers had created before they had followed the training. First, we will discuss the SDT-derived design principles of autonomy support and structure support.

The Importance of Autonomy Support and Structure Support

In a digital PBL task with autonomy support, external pressure is minimal (Deci & Ryan, 2000) and choices are offered (Reeve et al., 2003). The ability to choose among several options makes students feel greater control over their actions (Reeve et al., 2003). Another aspect of autonomy support is the provision of the rationale for a task. If students receive a meaningful explanation of why a specific learning task is useful, they are more likely to internalize the personal relevance of the learning task and become motivated to learn. Further, it is important that the language in the learning tasks is characterized by non-directive language that encourages students to take initiative rather than controlling language (Reeve et al., 2004a).

Research shows that environments that are autonomy-supportive help to fulfil the need for autonomy and foster greater intrinsic motivation in students (Reeve et al., 2003). However, PBL tasks with only autonomy support may create associative distraction and overwhelm students with an excessive number of choices. As a consequence, learners only construct shallow associative cognitive networks that have no intellectual merit (Okan, 2003). Thus, in addition to autonomy support, structure support plays a key role in an optimal digital PBL task (Guay et al., 2008). Structure makes the learning environment less chaotic and more consistent and predictable for students. Moreover, from a motivational point of view, structure increases students' perceived competence (Skinner & Belmont, 1993).

Structure support in digital PBL tasks involves providing students with clear goals and expectations and explicitly describing the consequences of achieving (or not achieving) these goals (Reeve et al., 2004a; Skinner & Belmont, 1993). Structure also involves providing students with help, support, and guidance to successfully carry out a task (Reeve et al., 2004a; Skinner & Belmont, 1993). Finally, structure requires providing students with clear procedures to follow (Reeve et al., 2004a). Structure is associated with positive learning outcomes as well as greater learner engagement (Skinner & Belmont, 1993).

Although autonomy support and structure support are important for all students, it is possible that there are differences between students in the degree to which they need autonomy support and structure support based on their age. Studies in the domain of neuropsychology indicate that students undergo age-related development during the school period, for example in their executive functions (Burrage, Ponitz, McCready, Shah, Sims, Jewkes, & Morrison, 2008). It is possible that older students with better executive functions need less structure support than younger students.

Training Teachers

Although research shows that both autonomy support and structure support in digital PBL tasks are important for motivating students, it is questionable whether teachers are able to apply these principles in digital PBL tasks. This application requires didactic teacher skills. Research shows that simply installing computers in schools and the presence of computers in the classroom do not change the didactic teaching methods of teachers (Stoddart & Niederhauser, 1993). Therefore, teachers should be trained in designing digital PBL tasks with the principles of autonomy support and structure support.

In addition, it is difficult to change teacher behaviour through training. Much of the research on teachers' professional learning activities is often characterized as ineffective (Hanushek, 2005). Teacher professional development has been disappointing because sustainable training effects and educational improvement require changes in teachers' beliefs and practices (Clarke & Hollingsworth, 2002).

Research on the professional development of teachers shows that to change teachers' behaviour, certain principles should be taken into account. First, teachers require time to develop, absorb, discuss, and practice new knowledge (Garet, Porter, Desimone, Birman, & Yoon, 2001). Thus, professional development that involves a significant number of contact hours over a long period of time is typically associated with effectiveness (Guskey, 2000). Second, teachers' learning should be situated and focused on authentic activities in the classroom (Garet et al., 2001). Research shows that teachers learn most effectively when the training is school-based and integrated into their daily work (Garet et al., 2001). And third, professional development has been shown to be more effective when teachers from the same school or year level participate collectively (Garet et al., 2001).

The Present Study and Hypotheses

This study examines whether teachers can be trained to apply the principles of autonomy support and structure support in their digital PBL tasks. The challenge is to train teachers so that they indicate increased skill in creating digital PBL tasks and that their tasks are more autonomy- and structure-supportive compared to the digital PBL tasks that teachers had made before they had followed the training. An additional goal is to increase primary and secondary education students' autonomy, competence, and motivation in these tasks. We specifically examine both primary and secondary education students (in particular, middle school students) to determine whether the teacher training has the same effect on students of secondary education as students of primary education. Students' motivation declines during their school career, beginning in primary education and continuing until they complete high school, with notable losses during the transition to middle school (Wigfield, Eccles, Schiefele, Roeser, & Davis-Kean, 2006). Thus, it is especially important for secondary school teachers to construct motivating learning tasks. This leads to the following hypotheses:

The first hypothesis is that after the completion of training, teachers will indicate that they are more skilled in creating digital PBL tasks and that their digital PBL tasks are more autonomy-supportive and structure-supportive than those prior to training.

The second hypothesis is that primary and secondary school students will experience greater autonomy and competence in digital PBL tasks that are designed by teachers after training than prior to training. In addition, we investigate potential differences between primary education students and secondary education students.

The third hypothesis is that primary and secondary school students will experience greater intrinsic motivation in digital PBL tasks that are designed by teachers after training than prior to training. In addition, we investigate potential differences between students of primary education and students of secondary education.

METHODOLOGY

Design

The research is based on a one-group pre-test–post-test design. To test hypothesis 1, teachers were asked to rate their skills in creating digital PBL tasks with autonomy support and structure support before and after the training. In addition, teachers were asked to assess the degree of autonomy support and structure support in digital PBL tasks that they had designed before and after the training. To test hypotheses 2 and 3, students were asked to complete a questionnaire about their perceived autonomy, competence, and motivation in a digital PBL task that their teacher had created before and after the training.

Participants

The study was conducted in the Netherlands. Participants were 184 fifth-, sixth-, seventh- and eighth- grade students of 20 classrooms. There were 121 fifth- and sixth- grade students from four primary schools (10 classrooms) and 63 seventh- and eighth- grade students from one secondary school (middle school, 10 classrooms). The mean age of the students at the outset of the study was 12.6 years (*SD* = 1.11, range = 10.6 – 16.3 years). A total of 86 boys and 98 girls participated. The schools were typical schools that did not deviate from other schools in size, population or learning outcomes. The average learning outcomes of the students from the participating schools were at the same level as those of their peers at other schools throughout the country (Dutch Inspectorate of Education, 2011). The teacher sample contained 20 teachers (10 primary and 10 secondary school teachers). A total of 11 female and 9 male teachers participated. We selected the teachers at the participating schools based on the following two criteria: 1) the teachers had affinity with creating digital PBL tasks and 2) they taught fifth-, sixth-, seventh- and eighth- grade students. Participation was on a voluntary basis.

Training

To train teachers in applying the principles of autonomy support and structure support in their digital PBL tasks, an experienced external trainer was employed. The training was based on the three principles described in the introduction to this article. The first principle, i.e., teachers require time to develop and practice new knowledge, was met by the significant number of contact hours involved in the training. The training lasted two months and consisted of three team meetings.

During the first training meeting, the trainer gave a presentation that explained the two concepts of autonomy support and structure support in digital PBL tasks. The empirical support for the assertion that students benefit when a digital PBL task supports their needs for autonomy and competence was shown to the teachers. After this introduction, more detailed information and examples of autonomy support and structure support in digital tasks were provided. Following this meeting, teachers were required to create a plan for implementing autonomy support and structure support in their digital PBL tasks. In the second and third meetings, which occurred two weeks and six weeks after the first meeting, respectively, teachers implemented both autonomy support and structure support in their digital PBL tasks. These tasks were relevant to the lessons in the classroom and could be used in the lessons. Thus, the second principle, i.e., teachers' learning is situated and focuses on authentic activities in the classroom, was met. During each meeting, teachers were not only coached on strengths and areas for improvement in their digital PBL tasks, but were also provided technical support in designing the tasks. After the last meeting, they completed their new digital PBL task and offered it to the students in their class. Because teachers from one school learned together, the third principle, i.e., teachers from the same school participate collectively, was also realized.

Procedure

At two moments, before the training and after the training, teachers were asked to complete a questionnaire regarding the extent to which their digital PBL tasks included autonomy support and structure support. In addition, they were asked to complete a questionnaire regarding their skill in designing digital PBL tasks with autonomy support and structure support.

Students were asked to complete a questionnaire regarding their perceived autonomy, perceived competence, and intrinsic motivation at two time points. The first time point coincided with a digital PBL task that their teachers designed before the training, and the second time point coincided with their teachers' post-training digital PBL task.

Measures

Perceived autonomy, perceived competence, and intrinsic motivation

To measure students' intrinsic motivation, we used the Intrinsic Motivation Inventory (IMI), which was originally developed by Ryan (1982). The IMI is a structured written questionnaire, and its reliability and validity have been confirmed by McAuley, Duncan, and Tammen (1987). The subscale "interest / enjoyment" of the IMI contains seven items that measure intrinsic motivation (e.g., "I enjoyed doing this task very much" and "This task was fun to do"). The perceived degree of competence was measured by questions based on the IMI subscale of "perceived competence" that consists of six items. For example these items are "I am satisfied with my performance in this task", "I was pretty skilled at this task", "After working at this activity for a while, I felt pretty competent" and "This was an activity that I couldn't do very well" (reverse coded). So these items determined whether students actually experience greater competence in digital PBL tasks. The perceived degree of autonomy was measured by questions based on the IMI subscale of “perceived freedom of choice” which consists of seven items. For example, these items are “I believe I had some choice about doing this activity”, “I felt like it was not my own choice to do this task” (reverse coded), “I didn’t really have a choice about doing this task“ (reverse coded) and “I did this activity because I wanted to”. So these items determined whether students actually experience greater autonomy in digital PBL tasks they attempted.

Each item is presented in the form of a statement and the respondent indicates his or her degree of agreement or disagreement on a 7-point Likert scale (with a score of 1 indicating “totally disagree” and a score of 7 indicating “totally agree”). In the current sample, the reliability was high for all three scales, intrinsic motivation (α = .91), perceived autonomy (α = .82), and perceived competence (α = .83).

Teacher report: autonomy support and structure support

Teachers were asked to assess their digital PBL task with respect to the two dimensions of autonomy support and structure support using a rating sheet. The rating sheet features two clusters of items to assess autonomy support and structure support. Each item is scored using a 3-point Likert scale (with a score of 0 indicating “not present” and a score of 2 indicating “totally present”). The items were taken and slightly modified from an existing questionnaire, the Teacher as Social Context Questionnaire (Belmont, Skinner, Wellborn & Connell, 1988).

The teachers scored the following three autonomy-supportive aspects in their digital PBL task: offering choices, providing a rationale and avoiding the use of controlling language. Offering choices in the digital PBL task includes choice about the content of the task, choice about the online sources that the student could search for information, and choice about information processing. Providing a rationale involves an explanation about the relevance of the task. In the digital PBL task, non-directive language was used (e.g., “You can make use of…,” and “You can do this task”). The reliability of the autonomy support scale was sufficient (α = .76).

Teachers scored the following three structure-supportive aspects in their digital PBL task: providing clear expectations for students, guidance for students to successfully carry out a task, and clear procedures to follow. Providing clear expectations in the digital PBL task includes clarity regarding the way in which the completed product would be assessed. Guidance for students to successfully carry out a task involves providing students with a roadmap of the stages required to successfully complete the task. Finally, clear procedures includes how long the students were allowed to work on the task and what they could do when they completed their work. The reliability was sufficient for the structure support scale (α = .79).

Teacher report: skill in creating digital PBL tasks

Teachers were asked to assess their skills in creating digital PBL tasks using a written questionnaire. Three items of this questionnaire measure skills in creating digital PBL tasks. These items are “I think I’m skilled in designing digital PBL tasks”, “I am able to make digital PBL tasks” and “I can design digital PBL task”. Each item is presented in the form of a statement and the respondent indicates his or her degree of agreement or disagreement on a 5-point Likert scale (with a score of 1 indicating “totally disagree” and a score of 5 indicating “totally agree”). In the current sample, the reliability was sufficient for this scale (α = .75).

Data Analyses

The first hypothesis, i.e., teachers will indicate that they are more skilled in creating digital PBL tasks and that their digital PBL tasks are more autonomy- and structure-supportive after completing the training, was tested by dependent t -tests.

To test hypotheses 2 and 3, i.e., students will experience greater autonomy, competence, and intrinsic motivation in digital PBL tasks that are designed by teachers after the training than before the training, three sets of multilevel linear models were constructed. Because the data have a two level- hierarchical structure (students at level 1 and students nested in classes at level 2), we used hierarchical linear modelling [HLM]. This method is necessary because using a traditional single- level statistical method for multilevel data can lead to problems such as violations of assumptions of independence, aggregation bias, heterogeneity of regression and spurious significant results (Hox, 2002).

Three sets of multilevel regression analyses were conducted to predict students’ perceived autonomy, perceived competence, and motivation. The first model was the base model with no predictors. This model examined whether the classes (second level) contributed to the variance of the dependent variable. In the second model, we added the predictor training as a fixed effect. In the third model, we allowed the effect of the predictor training as a fixed effect and as a random effect (to examine whether the effect of training varied by class). To examine the difference between primary and secondary school students, in the fourth model, the predictor training, school type and the interaction between training and school type were added as fixed effects.

RESULTS

Teachers' Perceptions (Hypothesis 1)

It was expected that teachers would report increased skill in creating digital PBL tasks after completing the training in applying autonomy support and structure support in digital PBL tasks. Furthermore, we expected teachers to indicate that their digital PBL tasks were more autonomy- and structure-supportive after the training than before the training (1). Table 1 reports the descriptive statistics, means and standard deviations of teachers' reported skill in creating digital PBL tasks and degree of autonomy support and structure support in digital PBL tasks before and after the training.

Table 1

Descriptive Statistics for Teachers' Perceived Skills, Perceived Autonomy Support and Perceived Structure Support in Digital PBL Tasks Before and After Completing the Training

	Before the training		After the training	
	M	*SD*	*M*	*SD*
Perceived Skill	2.92	0.85	3.86	0.65
Perceived Autonomy Support	1.70	1.22	4.05	0.89
Perceived Structure Support	2.75	1.37	4.10	0.97

The results showed that teachers indicated that they were more skilled in creating digital PBL tasks after completing the training than before the training ($t(19) = 3.41$, $p < .05$, $r = .62$). In addition, teachers indicated that their tasks were more autonomy-supportive ($t(19) = 8.29$, $p < .001$, $r = .88$) and structure-supportive after the training than before the training ($t(19) = 5.31$, $p < .001$, $r = .77$).

In conclusion, the results showed that the training significantly affected the degree of autonomy support and structure support in digital PBL tasks, according to teachers. Teachers assessed the degree of structure support within digital PBL tasks as higher than the degree of autonomy support. Teachers reported increased skill in creating digital PBL tasks after completing the training.

Students' Perceived Autonomy and Perceived Competence (Hypothesis 2)

It was expected that students would experience greater autonomy and competence in digital PBL tasks that were designed by teachers after the training than before the training. Potential differences between students of primary education and students of secondary education were examined (2). Table 2 reports the descriptive statistics, means and standard deviations of students' perceived autonomy and perceived competence in digital PBL tasks that were designed by teachers before and after the training for all students, primary school students (fifth- and sixth- grade), and secondary school students (seventh- and eighth- grade).

Table 2

Descriptive Statistics for Students' Perceived Autonomy and Competence in Digital PBL Tasks Before and After Teachers Completed the Training

	Perceived Autonomy				Perceived Competence			
	Before Training		After Training		Before Training		After Training	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
All students	4.73	0.95	5.23	1.07	5.09	0.88	5.54	1.02
Primary school students	5.06	0.83	5.29	0.98	5.25	0.81	5.47	1.08
Secondary school students	4.09	0.81	5.11	1.24	4.77	0.93	5.70	0.90

Perceived autonomy

Table 3 shows the estimates for the models of the predictors of perceived autonomy. The first model was the base model with no predictors. The class significantly predicted the perceived autonomy of students. Interclass correlation coefficients indicated that between-class differences accounted for 11% of the total variance in students' perceived autonomy. Thus, the specific class and specific teacher who designed the task predicted the perceived autonomy of students.

In the second model, we added the predictor training as a fixed effect. The results showed that the training significantly affected the perceived autonomy of students ($F(1, 347.84) = 25.18$, $p < .001$, $r = .26$). The class also significantly predicted students' perceived autonomy.

In the third model, we allowed the effect of the predictor training as a fixed effect and as a random effect. The results showed that the training significantly affected the perceived autonomy of students ($F(1, 14.70) = 22.97$, $p < .001$, $r = .78$). The class also significantly predicted students' perceived autonomy. In addition, the slope did not vary across students, and the slope and intercept did not significantly covary. Thus, the relationship between training and autonomy did not vary between classes.

The change of the -2 Log Likelihood from model 1 to model 2 was significant ($p < .01$). The change of the -2 Log Likelihood from model 2 to model 3 was not significant. Thus, model 2 provided the best fit to the data.

Difference between primary- and secondary school students. In the fourth model, the predictor training, school type and the interaction between training and school type were added as fixed effects. Training and class were also added as random effects.

There was a significant interaction effect of training and school type on the perceived autonomy of students ($F(1, 803.22) = 12.18$, $p < .01$, $r = .12$). This interaction was further investigated by conducting separate multilevel models on primary school students and secondary school students. The models specified were the same as model 4 but excluded the main effect and interaction term involving school type. These analyses showed that for primary school students, training significantly predicted the perceived autonomy ($t(396.51) = 2.06$, $p < .05$, $r = .10$). Training also significantly predicted the perceived autonomy of secondary school students ($t(5.12) = 5.15$, $p < .01$, $r = .91$). The increase in perceived autonomy from the PBL tasks that were designed by teachers before the training to the PBL tasks after the training was greater for secondary school students than for primary school students. See Figure 1 for this interaction effect.

Table 3
Multilevel Model Estimates for Models of the Predictors of Perceived Autonomy

	Model 1		Model 2		Model 3		Model 4	
	Estimate	*SE*	*Estimate*	*SE*	*Estimate*	*SE*	*Estimate*	*SE*
Fixed effects								
Intercept	4.93***	0.09	4.68***	0.10	4.66***	0.12	5.08***	0.12
Training			0.50***	0.10	0.53***	0.11	ns	
School type							0.99***	0.19
Training x School type							0.77***	0.22
Random effects								
Intercept (Class)	0.12*	0.06	0.12*	0.06	0.19*	0.09	ns	
Training					ns		ns	
Covariance					ns		ns	
-2*log likelihood	1055.090		1030.779		1029.010		1008.869	

Note. *p < .05. **p < .01. ***p < .001.

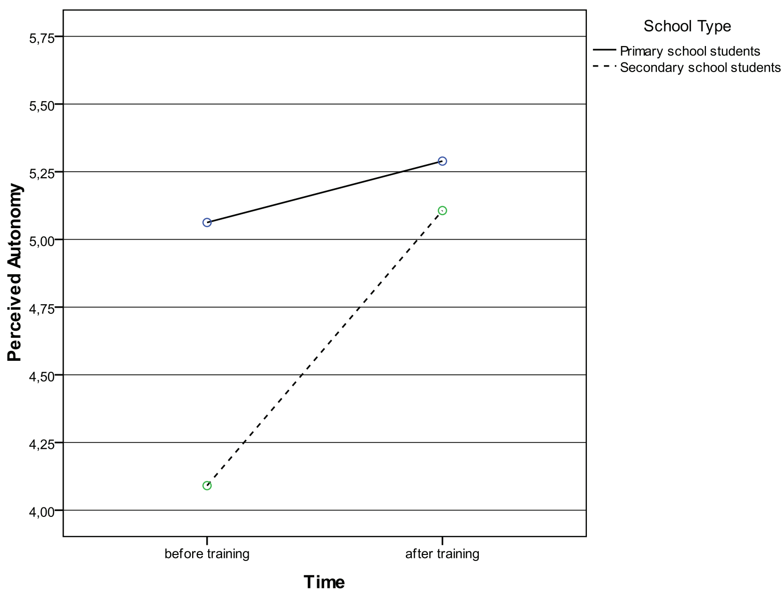

Figure 1. Perceived autonomy in digital PBL tasks of primary school students (n = 121) and secondary school students (n = 63) before and after teachers completed the training.

Perceived competence

Table 4 shows the estimates for the models of the predictors of perceived competence. The first model was the base model with no predictors. The class did not predict the perceived competence of students. Interclass correlation coefficients indicated that between-class differences accounted for 0.04% of the total variance in students' perceived competence. Thus, the specific class and specific teacher who designed the task did not predict the perceived competence of students.

In the second model, we added the predictor training as a fixed effect. The results showed that the training significantly affected the perceived competence of students ($F(1, 348.73) = 22.66$, $p < .001$, $r = .25$).

In the third model, we allowed the effect of the predictor training as a fixed effect and as a random effect. The results showed that the training significantly affected the perceived competence of students ($F(1, 444.86) = 22.56$, $p < .001$, $r = .22$).

In addition, the relationship between training and students' perceived competence showed no significant variance in intercepts across students, the slopes did not vary across students, and the slopes and intercepts did not significantly covary.

The change of the -2 Log Likelihood from model 1 to model 2 was significant ($p < .01$). The change of the -2 Log Likelihood from model 2 to model 3 was not significant. Thus, model 2 provided the best fit to the data.

Difference between primary- and secondary school students. In the fourth model, the predictor training, school type and the interaction between training and school type were added as fixed effects. Training and class were also added as random effects.

There was a significant interaction effect of training and school type on the perceived competence of students ($F(1, 436.99) = 12.19$, $p < .01$, $r = .17$). This interaction was further investigated by conducting separate multilevel models on primary school students and secondary school students. The models specified were the same as model 4 but excluded the main effect and interaction term involving school type. These analyses showed that for primary school students, training did not significantly predict the perceived competence. For secondary school students, training significantly predicted the perceived competence ($t(192.23) = 5.91$, $p < .001$, $r = .39$). The increase in perceived competence from the PBL tasks that were designed by teachers before the training to the PBL tasks after the training was greater for secondary school students than for primary school students. See Figure 2 for this interaction effect.

Table 4
Multilevel Model Estimates for Models of the Predictors of Perceived Competence

	Model 1		Model 2		Model 3		Model 4	
	Estimate	*SE*	*Estimate*	*SE*	*Estimate*	*SE*	*Estimate*	*SE*
Fixed effects								
Intercept	5.31***	0.07	5.08***	0.08	5.06***	0.10	5.25***	0.10
Training			0.46***	0.10	0.47***	0.10	ns	
School type							0.47*	0.17
Training x School type							0.72**	0.21
Random effects								
Intercept (Class)	0.04	0.03	0.04	0.03	ns		ns	
Training					ns		ns	
Covariance					ns		ns	
-2*log likelihood	1025.178		1003.225		1003.449		992.651	

Note. *$p < .05$. **$p < .01$. ***$p < .001$.

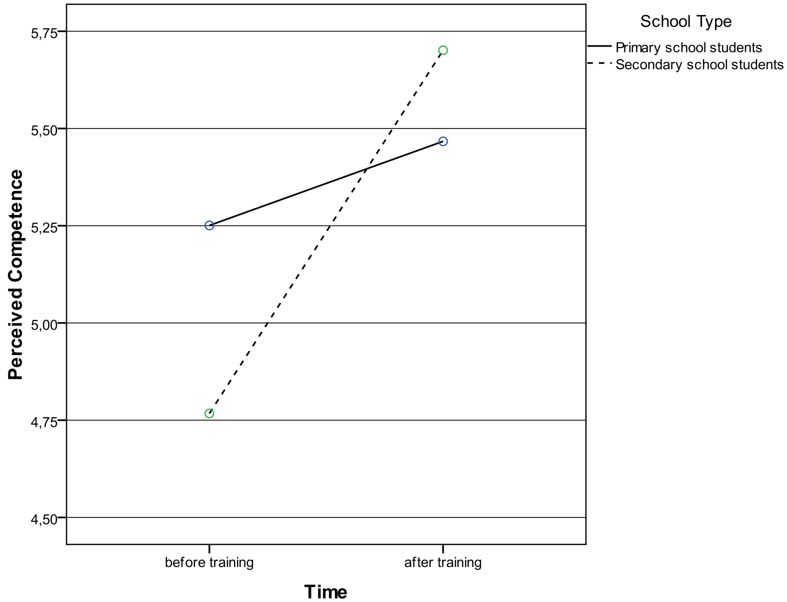

Figure 2. Perceived competence in digital PBL tasks of primary school students (n = 121) and secondary school students (n = 63) before and after teachers completed the training.

In conclusion, the results showed that the training significantly affected the perceived autonomy and perceived competence of students. The perceived autonomy and perceived competence scores on the PBL tasks after the training were higher than those before the training. The class significantly predicted students' perceived autonomy. Thus, the specific teacher who designed the task predicted the perceived autonomy of students. This was not the case for perceived competence.

The significant interaction effect between training and school type on students' perceived autonomy and perceived competence indicated that the increase in perceived autonomy and perceived competence for the PBL tasks that were designed by teachers before and after the training was greater for secondary school students than for primary school students.

Students' Intrinsic Motivation (Hypothesis 3)

It was expected that students would experience greater intrinsic motivation in digital PBL tasks that were designed by teachers after the training than before the training. Potential differences between students of primary education and students of secondary education were also examined (3). Table 5 reports the descriptive statistics, means and standard deviations of intrinsic motivation of students in digital PBL tasks that were designed by teachers before and after the training for all students, primary school students (fifth- and sixth- grade), and secondary school students (seventh- and eighth- grade).

Table 5

Descriptive Statistics for Students' Perceived Intrinsic Motivation in Digital PBL Tasks Before and After Teachers Completed the Training

	Intrinsic motivation			
	Before Training		After Training	
	M	*SD*	*M*	*SD*
All students	4.95	1.30	5.48	1.27
Primary school students	5.41	1.14	5.66	1.20
Secondary school students	4.09	1.18	5.15	1.34

Table 6 shows the estimates for the models of the predictors of perceived intrinsic motivation. The first model was the base model with no predictors. The class significantly predicted the perceived intrinsic motivation of students. Interclass correlation coefficients indicated that between-class differences accounted for 16% of the total variance in students' perceived intrinsic motivation. Thus, the specific class and specific teacher who designed the task predicted the perceived intrinsic motivation of students.

In the second model, we added the predictor training as a fixed effect. The results showed that the training significantly affected the perceived intrinsic motivation of students ($F(1, 348.17) = 18.49$, $p < .001$, $r = .22$). The class also significantly predicted students' perceived intrinsic motivation.

In the third model, we allowed the effect of the predictor training as a fixed effect and as a random effect. The results showed that the training significantly affected the perceived intrinsic motivation of students ($F(1, 530.87) = 18.53$, $p < .001$, $r = .18$). The class also significantly predicted the perceived intrinsic motivation of students. In addition, the slope did not vary across students and the slope and intercept did not significantly covary. Thus, the relationship between training and intrinsic motivation did not vary between classes.

The change of the -2 Log Likelihood from model 1 to model 2 was significant ($p < .01$). The change of the -2 Log Likelihood from model 2 to model 3 was also significant ($p < .05$). Thus, model 3 provided the best fit to the data.

Difference between primary- and secondary school students. In the fourth model, the predictor training, school type and the interaction between training and school type were added as fixed effects. Training and class were also added as random effects.

There was a significant interaction effect of training and school type on the perceived intrinsic motivation of students ($F(1, 380.47) = 9.86$, $p < .01$, $r = .16$). This interaction was further investigated by conducting separate multilevel models on primary school students and secondary school students. The models specified were the same as model 4 but excluded the main effect and interaction term involving school type. These analyses showed that for primary school students, training did not significantly predict the perceived intrinsic motivation. For secondary school students, training significantly predicted the perceived intrinsic motivation ($t(122.66) = 4.92$, $p < .001$, $r = .41$). The increase in perceived intrinsic motivation from the PBL tasks that were designed by teachers before the training to the PBL tasks after the training was greater for secondary school students than for primary school students. See Figure 3 for this interaction effect.

Table 6
Multilevel Model Estimates for Models of the Predictors of Perceived Motivation

	Model 1		Model 2		Model 3		Model 4	
	Estimate	*SE*	*Estimate*	*SE*	*Estimate*	*SE*	*Estimate*	*SE*
Fixed effects								
Intercept	5.12***	0.14	4.85***	0.15	4.82***	0.18	5.41***	0.16
Training			0.53***	0.12	0.58***	0.14	ns	
School type							1.31**	0.24
Training x School type							0.81**	0.26
Random effects								
Intercept (Class)	0.27*	0.12	0.28*	0.12	0.51*	0.23	ns	
Training					ns		ns	
Covariance					ns		ns	
-2*log likelihood	1214.732		1196.718		1190.571		1171.286	

Note. *$p < .05$. **$p < .01$. ***$p < .001$.

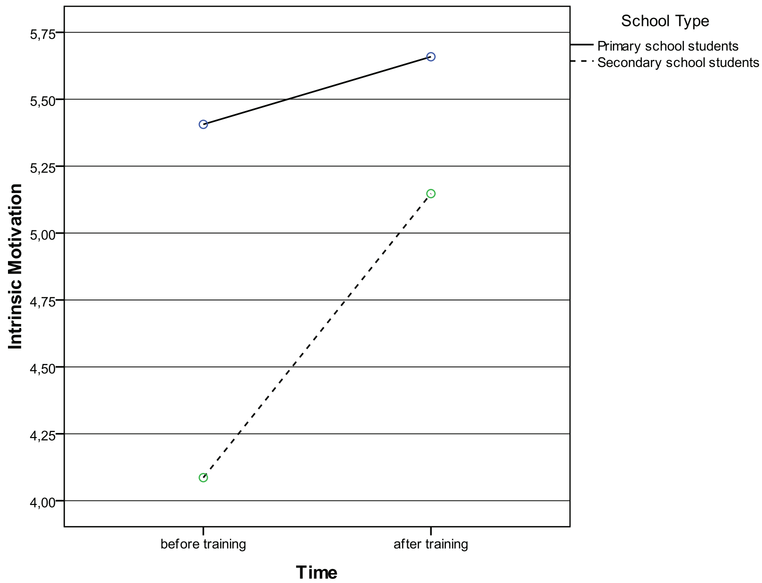

Figure 3. Intrinsic motivation in digital PBL tasks of primary school students (n = 121) and secondary school students (n = 63) before and after teachers completed the training.

In conclusion, the results showed that the training significantly affected the intrinsic motivation of students. The intrinsic motivation scores on the PBL tasks after the training were higher than those before the training. The class also significantly predicted the intrinsic motivation of students. The significant interaction effect between training and school type on students' intrinsic motivation indicated that the increase in intrinsic motivation for the PBL tasks was greater for secondary school students than for primary school students.

Discussion

This study examines whether teachers are able to apply the principles of autonomy support and structure support in designing digital PBL tasks. Previous research shows that digital PBL tasks with both autonomy support and structure support have a positive effect on students' intrinsic motivation and learning outcomes (Van Loon et al., 2012). Teachers experience difficulties in incorporating these principles into PBL tasks because they often believe that autonomy support and structure support are two opposite principles. However, autonomy support and structure support are two separate dimensions of a learning environment that motivates students (Jang et al., 2010; Reeve et al., 2004a). The current study is the first to examine teachers' ability to design digital PBL tasks with a combination of autonomy support and structure support. The study investigated whether training in the application of the combination of these two principles in digital PBL tasks can increase teachers' perceived skill in creating digital PBL tasks and the autonomy- and structure-supportive nature of the tasks. More importantly, we examined whether primary and secondary school students experience greater autonomy, competence, and motivation in these tasks.

The first part of the first hypothesis, i.e., teachers will indicate that they are more skilled in creating digital PBL tasks after completing the training, was confirmed. The results showed that teachers indicated that they were more skilled in creating digital PBL tasks after completing the training than before the training. In addition, the second part of the first hypothesis, i.e., teachers will indicate that their digital PBL tasks are more autonomy- and structure-supportive after completing the training, was confirmed. Teachers assessed the degree of structure support within digital PBL tasks as higher than the degree of autonomy support. Based on the low scores on autonomy support and structure support before training and the increase of these scores after training, training on these two principles is effective.

The second hypothesis, i.e., primary and secondary school students will experience greater autonomy and competence in digital PBL tasks that are designed by teachers after training than before the training, was confirmed. The results showed that students' perceived autonomy and perceived competence scores on the digital PBL tasks after teachers completed the training were higher than those before teachers completed the training. An examination of the difference between primary and secondary school students demonstrated that primary school students scored higher on perceived autonomy and perceived competence in digital PBL tasks before and after the training than did secondary school students. There was also an interaction effect between training and school type on perceived autonomy and perceived competence. The increase in perceived autonomy and perceived competence from PBL tasks that were designed by teachers before they completed the training to the PBL tasks after the training was greater for secondary school students than for primary school students.

The third hypothesis, i.e., primary and secondary school students will experience greater intrinsic motivation in digital PBL tasks that are designed by teachers after the training than before the training, was also confirmed. The intrinsic motivation of students on the digital PBL tasks after the teachers completed the training was higher than that before teachers completed the training. An examination of the difference between primary and secondary school students indicated that primary school students scored higher on intrinsic motivation in digital PBL tasks before and after the training than did secondary school students. Additionally, there was an interaction effect; compared to primary school students, secondary school students evidenced a greater increase in intrinsic motivation from the tasks before the training to the tasks after the training.

Previous research shows that students in secondary education are less motivated than primary school students (Wigfield et al., 2006). It is possible that these students' lower motivation scores are due to the lower levels of autonomy support and structure support provided by teachers in secondary education. In the current study, the baseline scores of autonomy, competence, and motivation of secondary education students were indeed lower. However, a relatively short teacher training on autonomy- and structure-supportive skills was associated with great improvement on these aspects among secondary education students.

Although the hypotheses were confirmed, some limitations must be considered. First, because the students were nested within different classes and taught by different teachers, the factor "class" was included in the analyses. Although the number of students was large (184), the number of teachers in this study was relatively small (20); therefore, the results should be interpreted with caution (Kreft & Deleeuw, 1998). In future studies, a greater number of teachers should be included. Second, the data on the teachers and students could not be compared with a group of untrained teachers. In this study, this limitation was partially overcome by the use of multiple methods of data collection (triangulation). The variables of autonomy support and structure support in digital PBL tasks were operationalized based on multiple perspectives, namely, teachers' perceptions of autonomy- and structure support in the PBL tasks and students' perceptions of the PBL tasks.

This study provides important guidelines for teachers who are designing digital PBL tasks based on constructivist learning in the class. To avoid information overload and ensure motivation, which is an important predictor of learning performance (Deci & Ryan, 2000), digital PBL tasks must contain a combination of autonomy support and structure support. Autonomy support provides choices, a rationale for a task, and avoids the use of controlling language. It ensures that students feel control over their actions (Reeve et al., 2003). Structure support provides clear goals and expectations for students and explicitly describes the consequences of achieving (or not achieving) these goals, provides help and guidance for students to successfully carry out a task, and provides students with clear procedures to follow. Structure support makes the learning environment less chaotic and more consistent and predictable for students (Guay et al., 2008).

This study shows that teachers can be trained to apply autonomy support and structure support in their digital PBL tasks. Teachers indicated that the tasks were more autonomy- and structure-supportive after they completed the training and students experienced more autonomy, competence, and motivation in these tasks. We believe that this success is due to the combination of the following design principles: teachers require time to develop, absorb, discuss, and practice new knowledge (Garet et al., 2001), teachers' learning should be situated and focused on authentic activities in the classroom (Garet et al., 2001) and teachers from the same school or year level should participate collectively (Garet et al., 2001). More research is needed to examine whether the effect of the training can be attributed to a particular principle or a combination of principles.

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